1. Scope

1.1 This procedure covers rating analysis methods for determining load ratings and fatigue life of shafts per AGMA/AWEA 921-A97 and ANSI/AGMA 6001-D97.

2. Referenced Documents

2.1 AGMA/AWEA 921-A97 Recommended Practices for Design and Specification of Gearboxes for Wind Turbine Generator Systems.

2.2 ANSI/AGMA 6001-D97 Design and Selection of Components for Enclosed Gear Drives.

2.3 GEARTECH Specifications:

CK1000	QP1000	Procurement process
CK2000	QP2000	Procurement specification
CK3000	QP3000	Bid solicitation and evaluation
CK4000	QP4000	Gearbox design audit
CK4300	QP4300	Shaft design audit
CK5000	QP5000	Quality assessment
CK6000	QP6000	Quality assurance plan
CK7000	QP7000	Manufacturing schedule
CK8000	QP8000	Manufacturing audit

3. Terminology

3.1 Definitions- See referenced documents for definition of terms.

3.2 L1 life- Adjusted life for 1% failure probability.

3.3 Reliability factor k_c- Factor accounting for statistical variation in fatigue strength. See ANSI/AGMA 6001-D97.

3.4 Fatigue safety factor F_{sf}- See ANSI/AGMA 6001-D97 for definition.

3.5 Peak load safety factor F_{sp}- See ANSI/AGMA 6001-D97 for definition.

3.6 Maximum fatigue load- The maximum load shown in the load spectrum.

3.7 Peak load- The momentary, maximum load agreed to by purchaser and gear manufacturer. The peak load may be due to emergency brake stop, generator short circuit, utility grid event, or other transient condition.

4. Significance and Use

4.1 Shaft rating analysis- The shaft design audit determines if shafts have adequate load capacity to conform to requirements of AGMA/AWEA 921-A97 and the procurement specification.

5. Procedure

5.1 Checklist and quality procedures- CK1000 through CK4000 and QP1000 through QP4000 shall be used as guidelines for required data for shaft design audits. CK4300 shall be used as a guideline for shaft design audits. See CK5000 through CK8000 and QP5000 through QP8000 for guidelines for quality assurance.

5.2 Specification conformance- Shaft rating calculations shall be performed in accordance with AGMA/AWEA 921-A97 and the procurement specification.

5.3 Geometric quality- Tolerances for diameters, lengths, surface roughness, straightness, circularity, parallelism, and radial and axial runout shall be reviewed considering requirements for operating accuracy of gears and bearings.

5.4 Fillets- Geometry of fillets at junctions of diameters and shoulders shall be reviewed considering requirements for clearance with mating components such as gears and bearings, and requirements for minimizing stress concentration.

5.5 Keyways- Geometry of keyways shall be reviewed considering requirements for fit with keys and minimizing stress concentrations.

5.6 Metallurgical quality- AGMA/AWEA 921-A97 requires all shafts be made from alloy steels with sufficient hardenability to obtain microstructures with strength and fracture toughness meeting the requirements of the application. Engineering drawings and quality assurance plan shall be reviewed considering requirements for metallurgical quality including inspections and tests.

5.7 Fatigue analysis

5.7.1 Rating method- Calculations shall be performed per AGMA/AWEA 921-A97, ANSI/AGMA 6001-D97, and CK4300.

5.7.2 Failure probability- Reliability factor shall be $k_c = 0.817$ (failure probability 1%).

5.7.3 Load for fatigue analysis- Fatigue safety factor, F_{sf}, shall be calculated using the maximum fatigue load.

5.8 Yield analysis

5.8.1 Rating method- Calculations shall be performed per AGMA/AWEA 921-A97, ANSI/AGMA 6001-D97, and CK4300.

5.8.2 Load for yield analysis- Peak load safety factor, F_{sp}, shall be calculated using the peak load.

5.9 Shaft/gear fits

5.9.1 Rating method- Torque capacity of interference fits shall be calculated per AGMA/AWEA 921-A97, ANSI/AGMA 6001-D97 and CK4300.

5.9.2 Load for calculating torque capacity- Slip torque shall be calculated using the peak load.

5.9.3 Coefficient of friction- Coefficient of friction shall be $f \leq 0.15$.

5.9.4 Keys- No benefit from keys shall be considered when calculating torque capacity.

5.9.5 Shaft/gear fits- The range of fits for shafts and gears shall be calculated from tolerances given on engineering drawings.

5.10 Deflection analysis

5.10.1 Rating method- Calculations shall be performed per AGMA/AWEA 921-A97, ANSI/AGMA 6001-D97, and CK4300.

5.10.2 Load for deflection analysis- Deflection shall be calculated using the maximum fatigue load.

6. Interpretations of results

6.1 Specification conformance- Results of the shaft design audit shall be compared to requirements of AGMA/AWEA 921-A97 and the procurement specification for the following categories:

- Geometric quality
- Fillets
- Keyways
- Metallurgical quality
- Fatigue safety factor
- Yield safety factor
- Shaft/gear slip torque
- Deflection

7. Acceptance criteria

7.1 Geometric quality- Geometric quality shall be consistent with requirements for operating accuracy of gears and bearings.

7.2 Fillets- All fillets shall have adequate clearance with mating components and adequate radii to avoid undue stress concentration. Surface roughness shall be $Ra \leq 1.6\ \mu m$.

7.3 Keyways- All keys shall be fitted to shafts with an interference fit. Inside corners of keyways shall have adequate fillet radii. Edges of keyways shall be deburred or chamfered. Keyways shall not extend into bearing journals.

7.4 Metallurgical quality- metallurgical quality shall be consistent with requirements for strength and fracture toughness.

7.5 Fatigue safety factor- Fatigue safety factor shall be $F_{sf} \geq 1.1$.

7.6 Yield safety factor- Peak load safety factor shall be $F_{sp} \geq 1.1$.

7.7 Shaft/gear slip torque- All shaft/gear fits shall have adequate torque capacity to transmit the peak load without slipping.

7.8 Deflection- Maximum deflection shall be consistent with load distribution factors used in gear rating (see QP4200). Maximum slope at bearings shall be within bearing manufacturer recommendations.

8. Report

8.1 Report- The report shall include the following:

8.1.1 Summary of geometric quality,

8.1.2 Summary of fillets,

8.1.3 Summary of keyways,

8.1.4 Summary of metallurgical quality,

8.1.5 Summary of fatigue safety factor,

8.1.6 Summary of yield safety factor,

8.1.7 Summary of shaft/gear slip torque,

8.1.8 Summary of deflection,

8.1.9 Recommendations for revisions to engineering specifications to ensure conformance to AGMA/AWEA 921-A97 and the procurement specification.